

402, 104 and 404 mate first when battery pack connector **400** and energy storage system connector **410** are joined, and unmate last when battery pack connector **400** and energy storage system connector **410** are separated. Control contacts **106** and **406** mate last and unmate first. The mating sequence therefore is power contacts mate, then control contacts mate. The unmating sequence is control contacts unmate, then power contacts unmate.

[0071] This sequencing is obtained, for example, through the relative physical sizes of the power contacts **102** and **402, 104 and 404**, and control contacts **106** and **406**, and by the relative positioning of control contacts **106** to the power contacts **102** and **104** in each connector.

[0072] As an example, a 120 Amp Powerpole connector used for power contacts **102, 104**, has a contact surface which is 0.84 inches (21.3 mm) in length. When two of these genderless flat wiping contacts, such as power contact **102** in battery pack connector **400** mating with power contact **402** in energy storage system connector **410**, the majority of this 0.84 inch contact surface in each contact touches its mating contact, thus this contact has a wiping length of 0.84 inches.

[0073] In contrast, the smaller pin and socket contacts typically used in miniature D-sub connectors (e.g. DE9, DE15, and DE25 used in computers and communications equipment) have a wiping length of 0.25 inches.

[0074] By aligning power and control contacts so the middle of the wiping length of each contact in the connector is aligned **420**, both power and control contacts fully mate. For the contacts of the example given, the middle of the 0.84 inch wiping length for a power contact such as **102, 104** is 0.42 inches. Similarly, the middle of the 0.25 inch wiping length for a control contact such as **106** is 0.125 inches. In a symmetric embodiment, aligning the middle of the length for these contacts, shown as **420** in the figure, is the same as spacing the control contacts 0.42 inches-0.125 inches, or 0.295 inches back from the front of power contacts **102, 104**, shown as **425** in the figure. When battery pack connector **400** and energy storage system connector **410** are mated, because of this alignment, power contacts **102** and **402, 104 and 404** will be connected and overlap approximately 0.295 inches before control contacts **106, 406** make initial contact. Similarly, when battery pack connector **400** and energy storage system connector **410** are unmated, when control contacts **106** and **406** have separated, power contacts **102 402, and 104, 404** are still connected with approximately 0.295 inches of travel until the connection is broken.

[0075] Many other embodiments are possible, relying on difference in the lengths of the two types of contacts. As an example, energy storage system connector **410** could be implemented so that the front surfaces of all contacts **402, 404, 406** are aligned. This would require that contacts **106** in mating battery pack connector **400** be set back from connectors **102** and **104**.

[0076] When battery pack **100** is not connected, it is in a safe state with one or both of switches **110 114** in their off state, isolating power contacts **102 104** from storage cells **130a 130b**. When battery pack **100** is inserted into energy system **10**, mating battery pack connector **400** and energy storage system connector **410**, master controller **150** senses battery pack **100**. This may be done, for example, by master controller **150** polling control buss **144** periodically for inserted battery packs. In an alternate embodiment, inserting battery pack **100** may generate an interrupt on master controller **150** indicating that a battery pack has been inserted.

[0077] When battery pack **100** is removed from energy storage system **10**, control contacts **106** and **406** unmate in the first few millimeters of battery pack motion. This unmating event is recognized by battery controller **120**, which places the battery pack in safe mode by opening one or both of switches **110** and **114**. This action insures that current flow from energy cells **130a 130b** through power contacts **102 402** and **104 404** has been interrupted prior to those power contacts unmating.

[0078] In one embodiment, this unmating may be detected by loss of communications with master controller **150** through buss **144** and contacts **406** and **106**.

[0079] Mating and unmating may also be recognized by battery controller **120** for example by a dedicated presence signal on control buss **144** and control connector **406**. A logic "1" signal may be placed on one control line for example by master controller **150**, or by a hard-wired pull-up; battery pack **100** provides a pull-down on this line, which is fed to battery controller **120**. When battery pack **100** is connected, this control line will be pulled up to a logic "1" at battery controller **120**, and when the battery pack is disconnected the control line will be pulled down to a logic "0" which is sensed by battery controller **120** to place the battery pack in safe mode. Logic levels may be inverted depending on the implementation.

[0080] In a further embodiment, a loopback line **408** may be provided on control contacts **406**. This loopback line may be used by battery controller **120** to sense when the battery pack is connected or disconnected. Disconnection places the battery pack in safe mode.

[0081] In an alternative embodiment, a sense line or a loopback line may also be used to enable and disable the drivers **112, 116** for either or both of switches **110** and **114** at a hardware level independent of battery controller **120**. Enabling and disabling switch drivers **112, 116** based on a control line or loopback provides a hardware failsafe which insures that battery controller **120** can only place the battery pack in a charge or discharge state when connected to the energy system, and that power from energy cells **130a 130b** to power contacts **102 104** is cut without requiring action from battery controller **120**.

[0082] It is to be understood that the examples given are for illustrative purposes only and may be extended to other implementations and embodiments with different conventions and techniques. While a number of embodiments are described, there is no intent to limit the disclosure to the embodiment(s) disclosed herein. On the contrary, the intent is to cover all alternatives, modifications, and equivalents apparent to those familiar with the art.

[0083] In the foregoing specification, the invention is described with reference to specific embodiments thereof, but those skilled in the art will recognize that the invention is not limited thereto. Various features and aspects of the herein-described invention may be used individually or jointly. Further, the invention can be utilized in any number of environments and applications beyond those described herein without departing from the broader spirit and scope of the specification. The specification and drawings are, accordingly, to be regarded as illustrative rather than restrictive. It will be recognized that the terms "comprising," "including," and "having," as used herein, are specifically intended to be read as open-ended terms of art.